Syntactic approach to electric mobility in metropolitian areas: NE 1 district core, segment map

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SYNTACTIC APPROACH TO ELECTRIC MOBILITY IN METROPOLITAN AREAS:
NE 1 district core, segment map

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Abstract

Capturing vehicular travel behavior is one of the most popular models that deal with relevant aspects of urban regions and communities. Since 1960s, it has been matured and evolved to cover all aspects of travel demand applications. Different theories are employed to predict the movement of trip makers' likewise metric method and the estimation of origin-destination matrixes, intervening opportunities method which counts more on probabilities, and finally the spatial configuration modeling. The latter is to apply topo-geometrical analysis to arrive at configurational measures that can optimally approximate movement patterns in the urban network. Space syntax is an alternative approach to estimate conventional vehicular travel demand without using O-D matrix trip data, which is difficult to be obtained.

Space Syntax is an alternative approach to predict the vehicular movement in urban systems using the concept of accessibility measures (syntactic measures and maps) which reflects the complexity of routes from a road segment to all the others within the system. The syntactic approach is employed in this study to simulate a particular mobility system; electric vehicles (EVs) cluster. Simulating EVs'-systems is a subset of the conventional traffic modeling entire group. In particular, EV modeling environment set-up and configurations differ due to the special paradigms and behavioral characteristic aspects the system has. EV market is a niche market though it is expanding. This paper maps the current EV systems and focuses on one of which that needs prompt actions to be taken to have a mainstream supported and reliable market of EVs. Charging service is a thorny problem annoys the current users and hinders potential users to switch to low carbon emission vehicle purchase option. The study area located in the North East region of United Kingdom is investigated in detail. Spatial configuratioal analysis of the inner urban core of the metropolitan area, Newcastle-Gateshead, NE1 is undertaken. This paper presents a methodology to integrate configuratiomal modeling of NE1 to simulate the mobility mode within the context. Spatial analysis and segment maps have been generated via the use of Depthmap research software. Real information about users was collected from the service providers to employ some the simulation assumptions. A multi model simulation modeling is developed while incorporating configurational modeling to build the urban layer of an EV simulation environment. Space syntax analysis is conducted by using the open source application, Depthmap. Simulation is developed via a commercial tool, Anylogic. The paper views the necessary steps of forming and analyzing the urban system facilitating the integration of EV system to run the simulation.

Keywords: *Electric Vehicles, spatial configurational modeling, segment map, multi-model simulation*

Theme: *Modelling and Methodological Developments*

1. Introduction

Transport is a vital spine for societies to deliver logistics solutions and enable mobility. Worldwide and especially across Europe, we have a range of technological opportunities and strategies available for the smart and sustainable transportation modes in the 21st century. Depending on which mode, fuel type, and the source we are choosing, the overall impact of the use is reflected, consequences are falling and the more the choice is greener, the less negative impact the mode to the environment (E. ElBanhawy et al. 2012). Over the past four decades, the environmental burden of road vehicles has become increasingly important. In response to that, environmental protection and energy conservation are growing concerns worldwide (Chan and Wang, 2004). Many of industrial developed countries are embarking on policies and programs to encourage and promote building new smart communities (Beeton 2012). Powering vehicles with electricity is of significant interest because innovation in battery technology, if dramatic enough, could constitute a breakthrough in the search for ways to reduce petroleum use. (TEP 2011)

1.1 EV in on the verge

In literature, it has been discussed that battery operated vehicles, Electric Vehicle (EV) is a promising form of technology pathway for cutting oil use and CO2 emissions (Elbanhawy, Dalton, and Thompson 2013). It is perceived as a central pillar for a new era of alternative smart and green means of transport. There is a growing momentum behind owning a plug-in electric vehicle (PEVs). However, it is too early to assert whether electrification will dominate the alternative equivalent vehicle market. Automotive Original Equipment Manufacturers - OEMs must recognize the growth strategy and how they should position themselves to win while alternative fuel technologies and infrastructure continue to mature. When considering these strategies, OEMs should recognize the complexities of merging the utility, automotive, battery and charging infrastructure value chains. New infrastructure and new business models must be considered (Accenture 2011). EVs offer considerable potential to make progress in a variety of wider environmental, societal and economic objectives (Wee at al, 2011), which accelerates the development of smarter cities (Lozano 2012). EV became a real option as a number of major manufacturers are launching a high quality, fully battery electric vehicle models onto the market ("Electric Car Buying Guide" 2013). Urgent challenges presented by carbon reduction targets, climate change concerns, air quality goals, and resources depletion threats; most developed economies are conducting low-carbon policies and investing on efficient energy technologies. They are relying heavily on the electrification of road vehicles especially in a single vehicle owner to achieve carbon reduction goals (Morton Schuitema, G., Anable, J. 2011). Yet, the EV is still replacing the secondary car in a multi-car owning households due to the range matter ("Electric Car Buying Guide" 2013).

1.2 The Drive behind EV-Range Simulation

EVs advocates' perceptions about the EV system in general, have their inflectional effects on potential users hence the market penetration level. Yet, the charging matter of electric batteries worries the users and puts more pressure on them with the more rigorous planning-ahead they have to make prior to any trip (E. ElBanhawy and Nassar 2013). Regardless the region or the EV geographical population, the perception of most of the early adapters is almost the same. This is due to the occurrence of the same troubles that hurdle the market and limit it's the penetration. Basic questions are asked to potential users to determine if the EV is the most suitable choice, two of which are (1) the eternal access to off-street charging infrastructure and (2) average daily mileage, based on the region and the urban pattern, should be less than 80-100 miles ("Electric Car Buying Guide" 2013). Commenting on the first point, for instance, in the States of America, and based on a very recent survey was conducted by the author among a number of Eastern Electric Vehicle Club 20 users, EEVC (Perry 2013), the car-owning households asserted that if they don't have this domestic level of charging, they will critically reconsider the whole idea of owning an EV (E. ElBanhawy 2013). In the UK, a recent research claims that around 80% of UK drivers rely on domestic charging (50% urban, 70% suburban, and > 95% rural) (McDonald, 2012); ("Electric Car Buying Guide" 2013); (Warburton 2013). This reflects the most common, convenient, reliable mean of charging is to have a direct access to domestic charging which basically in their garages This leads us to another intrinsic question, what will be the case of multi residential neighborhoods? The second point is considering the daily mileage of the users and having sort of a predefined regular route. This is considered as one of the deal breakers while thinking of getting a new car. Based on the region and the urbanization of the area, the calculation of the average differently differs. In the USA, the average daily mileage is 40 miles where in the UK is 10 miles (Brain 2012) which leans to be more convenient to UK drivers to own EVs rather than US residents. Regular commuting trips would be a perfectly suited living pattern to EV properties. A routine journey that the driver is already with the distance, congestions, road conditions and parking availability ("Electric Car Buying Guide" 2013).

1.3 EV Casts Mapping

The current situation of EV system can be classified as per the following mapping of figure (1). From a closer look into the literature, and by scanning the current EV systems in different regions, the EV system(s) classification can be narrowed to four classes in terms of populations and systems. The first population a low carbon emission vehicles-oriented ones who depend on domestic charging and not looking for a publicly available charging point where EV is always the second car the households own, *Short-term managing*, SM. The second cast is a population who is less oriented and less involved in the EV market and having an extensive number of charging points which is underused due to many reasons and the authorities and stakeholders are struggling to emerge the market, *demand-less supply*, DS. The third population forms a more mature market with a nonexistence of / poor and unreliable public charging infrastructure where the users cannot depend on domestic charging to replenish their batteries, *Users demanding*, UD. And finally, the emerging market of potential users. A cast which is on the verge of endorsing a perfect environment for an EV system, in terms of users and urban pattern though needs a well-studied planning and policies to launch EV as a soft and hardscape, *Superior greenfield*, SG.

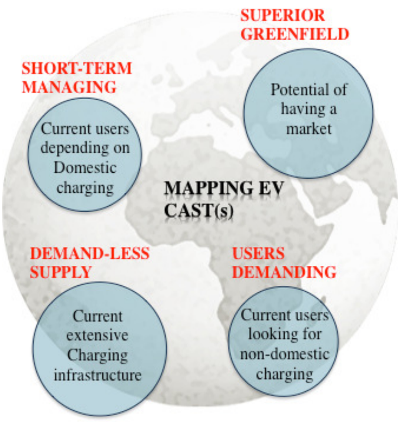


Figure 1: EV casts mapping

1.4 Focus of the study

This study focuses on the second and potentially the third system which both need prompt planning to open channels for stakeholders to support their EV market. The second cast is encountering crucial commercial and usability hurdles which are mainly the underused investments. Hence, the planning authorities and policy makers need to work on stopping the inefficiency and have proper planning for new investments to fill the charging service of possible third-cast occurrence. The aim of the study is to investigate the potential locations for charging infrastructure in a particular urban system. It focuses on planning for public and non-domestic available points. This happens via five main pillars: (1) incorporating accurate *urban layer* analysis, (2) depicting behavioral characteristic of the crowd, (3) employing a reliable interactive simulation platform to present the phenomenon, (4) setting a system performance measuring technique to spot the gaps in the infrastructure, (5) accounting for the system parameters and variables and trying different realistic scenarios and feasible assumptions. This objective is to hinder the expected underused charging points to be installed. Simulation solution is the selected research tool incorporating syntactic measures to build the model. The paper provides a methodology to analyze the *urban layer* by configurational modeling via space syntax idioms and measures and incorporating the EV population. The employment of configurational modeling in traffic analysis, is not a greenfield area of study, however, applying space syntax to EV population emergent behavior in the selected urban pattern is entirely new.

1.5 Train of Thoughts

This study presents an approach to study in depth the EV system in metropolitan areas. The EVs are denoted in the simulation as heterogeneous agents while their flow of movement in the road networks is simulated using discrete event-(DE)-technique. The paper starts with an explanation of the selected urban context and evaluation of the potential of space syntax in the area of predicting the EV movement. This is followed by the simulation and configurational modeling sections which discuss the model layers, technique, objective and the syntactic measures and maps of the study area, NE1. The simulation analysis follows with a thorough discussion and breakdown of the model development process followed by outcomes and discussion.

2. URBAN DESIGN EXPERIMENT

With special focus on the North East region of the UK as being an active region, the research claims that the charging infrastructure is more than enough to make EV a viable transport option. This is apart from the other factors that affect the market. The infrastructure is set to play a key role in our transport systems (Warburton 2013). Newcastle city is one of the greenest cities of the UK (Jha 2009) and it is considered as the second cast, AS, of the EV systems' classification explained earlier. The North-East is to become the UK's electric car capital, with plans to install up to 1,000 charging points around Newcastle and Gateshead metropolitan areas over the next two years. Local authorities and universities have been active in the context of low carbon emission vehicles research and development with a proven success in providing initiatives and schemes and participating in green/smart programs. The problem falls under this area as the planning needs to be well studied. According to the latest updates from the Newcastle civic center, sustainable transport department, there are 150 charging points in Newcastle and Gateshead where 40% of them are underused. This EV system forms the UK's most extensive charging network with over 500 publicly available charging points. In the North East, there are 12 fast-charging points(Type 3), which charge the battery from 0 to 80 percent in 20 minutes (Warburton 2013).

2.1 Space Syntax as an EV System Assignment

Space Syntax based modeling permits analysis of complex environments in a straightforward and cost-effective manner likewise transport system. The dynamic and evidence-based approach does not rely on origin-destination data, O-D matrix, but does integrate spatial layout, land use and transport attraction characteristics. Space Syntax modeling is therefore faster, less cumbersome and less prone to incorrect assumptions than either Movement Assignment or Dynamic Entity modeling (Murrain 2013). The spatial layout of urban places exerts a powerful influence in human behavior. The way the spaces connect is directly related to the way people move, interact and transact. Urban space can organize the movement to, through, and within spaces. From a behavioral point of view, this assumption postulates that the cognitive complexity of the route, described as the number of directional changes on a route, is the primary consideration in path choice, even more so than metric distance. Thus it is expected to prefer routes that involve less turns along the way, rather than shortest routes (Hillier et al., 2007). Former studies and analysis done in the space syntax area of study have shown that people tend to take the simplest path/ least angle change rather than shortest metric path between two nodes (Stonor 2011).

The angular route choice model can be incorporated to more sophisticated models of movement likewise found in transportation network analysis. This is applied by simply swapping the shortest distance criterion for angle, rather than physical distance (A. ; Turner 2007). The approach allows simultaneous analysis of multiple scales of movement from local to regional, national and international (Murrain 2013). A certain level of certainty of EVs' movement prediction is well captured through the cluster analysis operated by DepthMap and AnyLogic. Integrating space syntax analysis in the simulation modeling opened up to the depth investigation of the correlation between the structural properties of the system and the relevant dynamics within the system (Abhijit 2009).

2.1.1 Spatial Network Analysis

The idea of the configurational modeling revolves around the space theory that incorporates the space topological relationships and its relation with the movement. It has been also asserted though can't be generalized that the principle of configuration models, street segments with high accessibility indexes strongly present a high level of connectivity with other links hence high potential uses (Barros, De Silva, and Holanda 2007). It can be observed from the study presented by Barros, De Silva, & Holanda (2007), that configurational modeling in general and space syntax in particular can play a role in the transport studies specially in the early planning stages. This study employs space syntax spatial analysis software, Depthmap. Depthmap basically transforms the street pattern into a network graph by disaggregating the network at the intersections. The travel cost between a pair of segments, is measured by the shortest path approach (Murrain 2013). From road center-line map of the system (A. ; Turner 2007) the required segment map is developed where each line in the road network is divided into a segment at every connection point with other axis (A. Turner 2004). Having road segments fits more with the nature of transport studies as for assigning travel costs, adding different attributes and having detailed traffic analysis and assignments at a micro-scale level of the system, street segments' level (Barros, De Silva, and Holanda 2007).The distance is weighted by three key cost relations: connectivity, angular integration (Topo-geometrical) and depth.

3. Modeling and Simulation

Denoting the EV population in the inner urban core of Newcastle Area simulates a journey over a space. The first step to build the simulation environment is to understand the role of each element and abstractly draw their architecture. The simulation elements are the EVs, the road-networks, charging pattern of the users, and finally the charging points. Each element has a special and spatial characteristic and interacts with other elements and the environment intuitively, separately and differently. The simulation mode consists of two main layers: (1) *the urban layer* which is the road network and the vehicle movement prediction. In this layer the understanding and integration of configurational and syntactic modeling takes place. (2) *The behavior mode of the driver* layer which passed through two phases; (a) *driving safe mode* and (b) *critical battery zone*. This layer with its two modes forms the emergent behavior characteristics of the simulation. Nevertheless, by plotting the occurrence of this layer, the zones which need charging service are to be plotted and identified, figure (2).

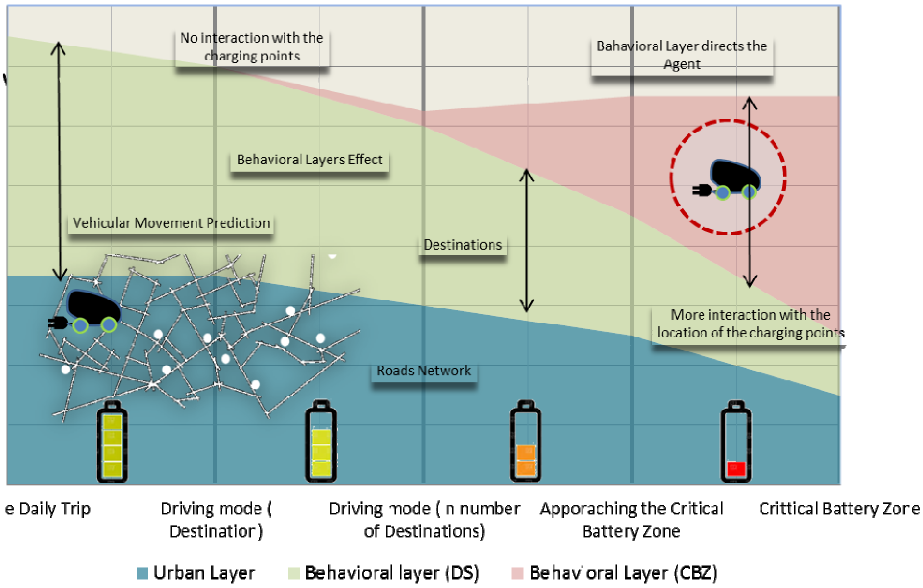


Figure 2: EV Simulation Layers

The simulation using Anylogic is presenting a hypothetical virtual presentation of EV population in Newcastle-gateshead area. Following the EV casts mapping, the study area is classified as the second cast, *Demand less Supply*, DS. Hence, to identify the urban zones that need charging service, we will run the iterations of the model without denoting the charging points. The simulation uses multi-model simulation technique. The hybrid model employs discrete-event (DE) to set the network and all related events within the EVs drivers' daily routes and agent-based modeling (ABM) to portray the emergent behavior of EVs population. Starting with the EVs, an individual behavior is being examined; thus, drivers will be agents. These agents are similar in their architecture as each one follows the same logic though different attitude/ behavior. In ABM, agents are used when there is an individual behavior / characteristic stemming from diverse capabilities of a moving entity (dynamic) needs to be denoted (Sarjoughian, Sarjoughian, and Dongping 2005). This is the predominant computational paradigm for agents; it stands in contrast to the message/event paradigm for DE. Also the agents compute and they never persist unless ordered unlike the events in DE. (Riley and Riley) (Balch 1998); (Garling Thøgersen, J. 2001) (Gerkey, Vaughan and Howard 2003); (Gerkey, Vaughan and Howard 2003). The rationale behind choosing the hybrid simulation modeling, and more details about the techniques can be found (E. ElBanhawy et al. 2012) (E. ElBanhawy, Dalton, and Nassar 2013) This study would focus more on the implementation part.

3.1 Demand of Charging Service-Zones Plotting

The simulation works as determining the second *behavior layer* of the drivers when the *critical battery zone* is approached and the driver starts running on almost an empty battery. The platform is a JAVA script based program. The *urban layer* with all the road networks is created as a DE in the main simulation *working space*. The vehicle is an entity, *class*, moves within the network (*DE*) and the battery itself is a generated *Agent* inside the entity. With each and every entity generated, an agent is created to denote the battery state of the vehicle. The model simulates a random group of EVs with different states of battery. The model is programmed to plot the critical zones within the network that need charging services. The case study explained below shall clarify.

4. Spatial Configurational Modeling

The configurational models have shown successful as prove to be cheaper and faster than conventional traffic models especially for the first investigation stage of an urban system where zoning, potential flows, possible bottleneck connections take place. These analyses usually depends, to name but a few, on identifying segregated and integrated areas, land use, topological-demographic analysis and generating origin and destinations (O and D) matrixes (Barros, De Silva, and Holanda 2007). The configurational modeling of NE1 starts with generating road network centerline mapping via using AutoCAD, fig. (1) And converting it to a segment map. In Depthmap, different space syntax analysis is applied to the segment map generating more attributes to the district road network (Fig.2 and Table 1). The study aims at providing guidelines and recommendations to locate preliminary charging points and determine their numbers and capacities, which should be of interest to researchers, planning authorities and policy makers. This paper is a part of an EU project that focuses on simulating a part of the North Sea Region e-mobility system. Through a configurational analysis of a street network, the Space Syntax methodology investigates relationships between spatial layout and a range of social, economic and environmental phenomena. These phenomena include patterns of movement, awareness and interaction; land use density, land use mix and land value; urban growth and societal differentiation; safety and crime distribution (Charalambous and Mavridou 2012).

4.1 NE1 Postal Zone

NE1 presents several express and arterial long roads, which vary in width, speed and capacity. According to Newcastle City Council (NCC), the Highway Authority for Newcastle upon Tyne, there are seven road types, three of which are displayed in the urban simulation environment. The three categories are the middle ones in terms of size, service and speed as at a bigger scale of the network, the trunk and principle roads are secluded, where down to the slightest segments likewise shared surfaces and home zone accesses are eliminated. The urban road network features affect accessibility which is determined by the location of the attractions within the network, and the possible access to reach them. Newcastle has a high mobility flow which allows drivers to live farther away from city center opportunities forming a centralized inner urban core, Figure (3d). The hierarchy of arteries, avenues and streets shows the topology of the network forming an integrated road network. The area is NE 1 postal district with a total population of 3959 with a total area of 814.33 km2. The area has the main traffic arteries of the city and has 50 publicly available charging points, table (1). Parking in the city center is offered for free after five o'clock which reflects more flow and crowded avenues to get in the business district network (NE1 2009). The map with all related needed attributes are provided by Edina, the National Academic Data Centre at the University of Edinburgh and Newcastle Civic Centre Data Center. Simulation input data is based on users' real information and their usage which is provided by Charge Your Car, EV local service provider for the UK Northeast region. The roads' hierarchy displayed in the *urban layer*, Figure (3a) starts from (1) collectors/ residential street (*Access*) 6.00 meter standard width, (2) local distributor road (*local*) standard width 6.75m standard (3.45m lanes) and (3) classified road (*District*) 7.30m standard width (3.65m Lanes). And the color scheme is red, green and blue receptivity. A solid and void representation showing the buildable areas and roads in an inverse ways off, figures (3 b, and c). NE 1 contains a versatile land use and pretty busy avenues and streams of movement whether pedestrian or car/ bus passengers. In contains the city center of the metropolitan area, two universities, schools, shopping and recreational areas, commercial buildings, train station, squares, parks, and partially, most of the busy residential wards of Newcastle area. NE1 is a virtuous experimental area to be syntactically studied. It is a rich area to study the flow of EV system and the behavioral characteristic of the users are to be studied study area that is rich of trip assignments and movements to give a good enough representation of a mobility system. The system shall denote two modes of EVs' drivers: (1) *Part-time drivers*, those who are coming from different areas around the city to possibly work study and entertain. (2) *Full-time drivers*, who live within the NE1 while work in/ outside.

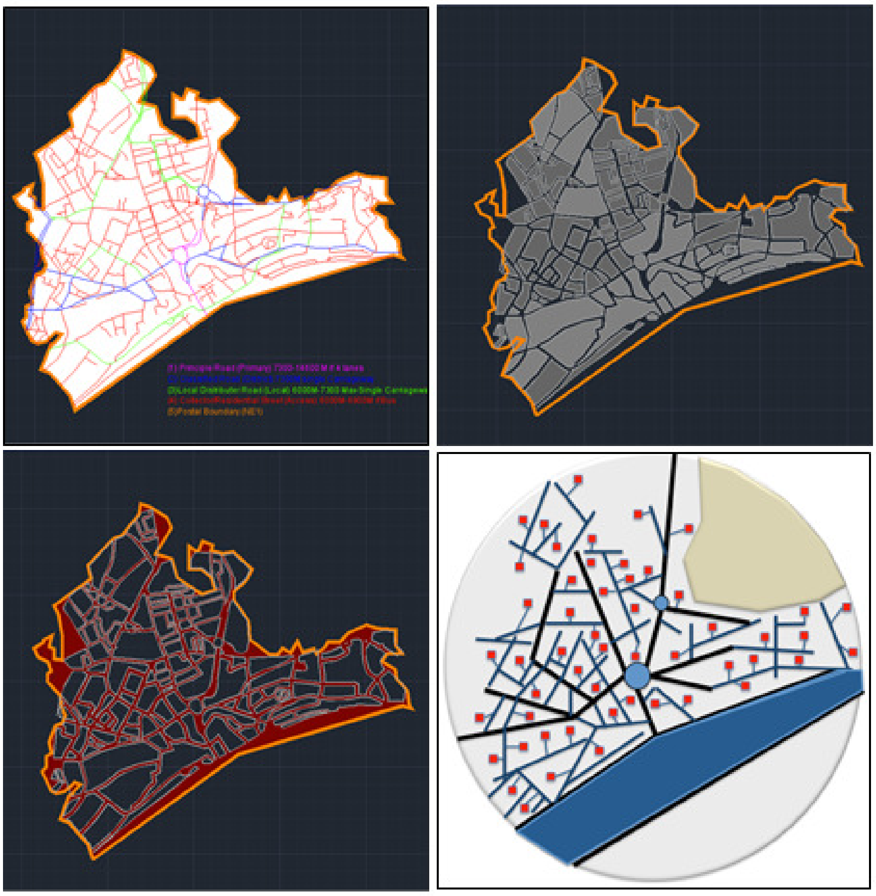


Figure 3a, b, c and d: Centralized road network of NE 1

4.2 Segment Map-Urban Core of NE1

The area contains main arteries and the most active road-segments, as it is the city center zone. For a partial simulation modeling, the focal plot of the selected area has been selected, highlighted in green, figure (4a), with respect to NE1 as whole. This green area consists of 100 road-segments. To apply the desired syntactic measures, the *buffer zone* was calculated forming an extended area of 500 meters away from the main arteries of the core being studied to avoid the edge effect. However, due to the strong natural boundaries of the selected area, the *buffer zone* is asymmetric with no regular radius. The circle in figures (4a and 4b) show an extended circular zone for illustration where the green area has a number of 100 segments and the *buffer zone* has 400 segments. Hence, the *buffer zone* of the green area highlighted in figure (4a), has the minimum margin at A side (segments 88, 84, 79, 76 and 61) and B side (segments 286, 282, 262, 270, and 209) are which still works on eliminating the edge effects. Where C side and D side are identified by the natural boundaries, B1311 Street, Percy B1307, Blackett Street-New Bridge Street and the Tyne and the Quayside, respectively. The study area including the *buffer zone* was drawn into a road-center lines map and a segment map, producing 400 road-segments, figure (4c). This process has been repeated and reviewed several times to ensure reaching the finest and most accurate version of the syntactic map. From defining the *buffer zone*, to getting a scaled map of the selected area, to drawing it in a 2D road-center lines map while trimming edges, verifying intersection points, deleting duplicate lines/layers/dots, to convert the drawing map into a segment map. The latter one is done via Depthmap in addition to other syntactic measures added later to the segment map.

Figure 4 a, b, and c: NE1 Postal Zone

5. The Myth of Mapping the EVs.

This section of the paper discusses the myth behind the mapping of EVs. Spatial configurational modeling has been applied to the area of study, figure (4C). From a behavioral point of view, this assumption postulates that the number of directional changes on a route, is the primary consideration in path choice, even more so than metric distance and thus it is expected that trip makers prefer routes that involve less turns along the way, rather than shortest routes (Hillier et al., 2007). Some syntactic measures have been calculated and displayed, figures (5a, b and c). Figure 5a shows the *angular connectivity* of the area. For instance, and with respect to the NE1 inner core, Westgate road, and Collingwood streets are the most accessible arteries with high values of connectivity, denoted in more reddish colors. Figure (5b), presents the *integration* values based on angular segment analysis (including betweeness) and radius type angular. Lines are displayed in a range from deep blue to deep red; blue signifying segregation and red signifying integration. Figure (5c) shows the urban spaces and plots of the selected area (59 spaces). The selected area is well-studied in Depthmap to get the necessary syntactic measures needed for the purpose of the study. The following step was to convert the segment map (100 segments) into a simple form of network in order to simulate the system, *collective segments*. The spatial measures have been tabulated in table (2) that starts with the space syntax segments, to the AutoCAD ID of the summed up segments, *collective segments*.

Figure 5 a, b and c: Buffer zone syntactic modeling

For instance, segments spaces Syntax ID (127, 128, and 130) are denoted as AutoCAD ID#11, figures (6b and c). This process happens to the segments which do not have any intersection point between them. As segments that have intersection points in between, cannot be merged. The table also shows the average values associated with each and every segment: connectivity integration, angular depth. For validation purpose, real traffic information about some major arteries is displayed; traffic counts. The last column shows the road hierarchy which was earlier explained by the speed associated.

	Road Network Segements	Urban Layer		Network Lines' Comulitive Space Syntax measures			Traffic Analysis		
	Space Syntax Line ID	AutoCAD ID		Connectivity	Integration	Angular Total Depth	Traffic Counter	Motor/ Day	Lanes
1	84	1	Westgate Road	3	59,7404	2417.12	10	32	Classified Road (District)
2	87	2		5	59,6794	2419.59			
3	89	3		5	59,5649	2424.25	9	205	
4	329	22		4	59,5217	2426.01			
5	322	23		3	59,6258	2421.77	1	24	
6	319	46		3	59,6674	2429.28			
7	133	25		4	59,4136	2430.42	5	187	
8	132,131	26		3	49.60925	2647.175			
9	135	28		4	60,5362	2385.35			
10	65,66	7	Neville Road-A165	3	49.3828	2924.44			Classified Road (District)
11	68,70,395	9		3	51.6436	2796.20333			
12	127,128,130	11		3	52.5263	2756.96667	8	16	
13	399-134-136	27		3	52.6807	2741.18667			
	138-137	29		3	54.9137	2646.73			
14	140	31		3	55,4477	2604.25	6	43	
15	141-143-144	32		3	56.5017667	2562.46333			
16	145	33		4	66,022	2187.15			
17	148-147	34		5	66.42935	2173.74			
18	111	13		5	52,53	2748.91			Locl Dist
19	112,338	16		3	2762.865	2762.865			
20	330,321,320	18	rainger	3	41.6282333	3469.33667			Collector/ Residential
21	312,313,314,315	21		3	58.424425	2471.7025			
22	311	24	Goat	4	66,3529	2176.24			Locl Distri
23	309,308	19		4	66.7314	2163.92			
24	305,306,307	37	St John grey Street	3	62.1428	2241.00333			tor/ Resid ential
25	299,298	41		4					
26	139	30	Colling Wood St A186	5	61,4648	2349.31	4	26	fied Road (District)
27	149	35		6	62,8142	2324.73			
28	152	36		3	62,1217	2324.47			
29	295	43		3	67.4665	2140.32			
30	296,297	44		3	68.4382	2110.325			Collector/ Residential Street (Access)
31	153-154-155-156-157-158-159-160	45	St.Nicholas Street	3	58.9784667	2454.65556			
32	108,110	14	Fenklest	4	47.0207	3070.815			
33	328,325,224,323	15		3	48.69095	2970.515			
34	118,119,122,123	10	Bewick	4	44.1963	3276.4075			
35	310	38		4	68,1112	2120.06			
36	304,301,300	39	HighBridge	4	68.3029333	2117.195			
37	388	40		4	68,7441	2107.57			
38	86,92	4	Cross Str Wate	4	51.26735	2816.605			
39	83,80,77	5		4	50.0685667	2785.37			
40	75,72	6	Fort h Pl	4	45.41535	3080.31667			
41	64,71	8	Clayton Road	3	50.99695	2832.41			Classified Road
42	114,115,117	12		3	53.8233667	2683.36	11	32	
43	335,333	17	N e w Bi gg M	3	64.68275	3188.34			Locl Distrib
44	331	20		4	65,849	2191.4			
45	391-392-290-291-292-293	42	Pilgrim Street	3	7.723492	9.133484			Collector/ Residenti

Table 2: Road-network segments analysis

From drawings, it can be observed that the area simulated in Anylogic is focusing on the eight main roads of the inner urban core: *Westgate Road, Mosley Road, Akanside Street, Melbourne Road, City Road, A167, NewBridge Street* and *Neville Road*. Another spatial analysis can be conducted is the J graph for the 46 The J graph, figure (6a), of the area shows the steps taken to reach every segment out of the 46 '*collective segments*'. The depth starts with the graph root which is the system *checkpoint* that all the entities shall originate from, explained later this section.

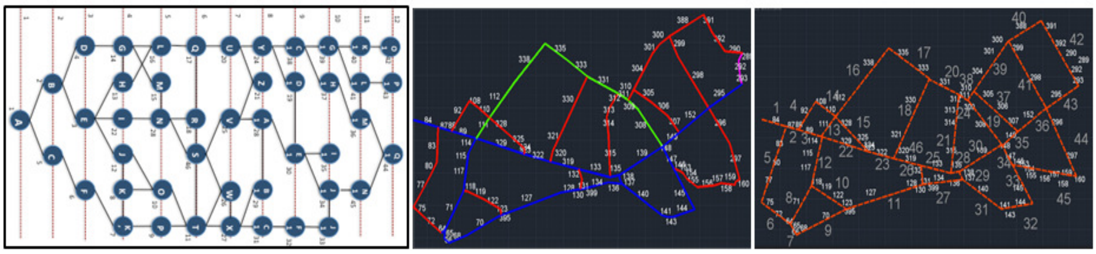
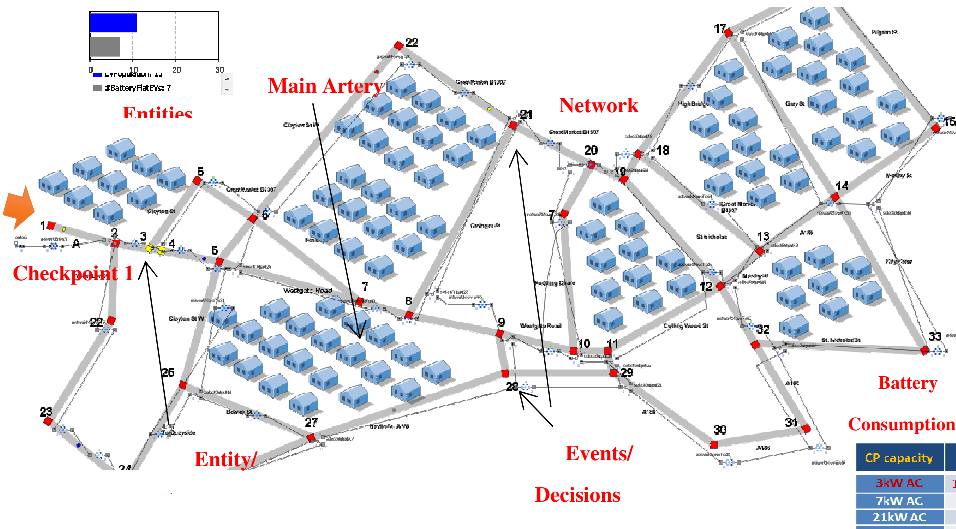


Figure 6a, b, and c: Inner core of NE 1 segments

5.1 Simulation Paragon

This part of the section depicts the simulation main paradigms. For a random simulated EV population, having a journey over space, for a period of time, the model iterations are taking place. Modeling the inner urban core of NE1 postal zone, the first occurrence of the EV population happens at a checkpoint (1), located on the border of the study area at a certain point on Westgate road. According to the World Bank database 2010, the percentage of UK car-owners is around 45%. This means, out of the population of NE 1, around 1780 residence own cars (*full-time*). This is in addition to the part-time passengers commuting to/from NE1. For simulation purposes, we shall consider another 85% as part-timers, 1485 cars. While considering commuters who are coming from the western side of NE1 entering from the checkpoint, 75%.

By applying a reasonable percentage of EV owners out of the population presenting the niche market, (7.5%), 179 EV entities are considered as the EV population. Figure (7) shows the elements of the simulation main environment class.



Location (On Street)	No	location (Off Street)	No
Akenside Hill	1	Argyle Street	1
Bigg Market	2	Civic Centre	8
Blandford Square	2	Close/Swing Bridge	1
Chillingham Road	1	Condercum Road	2
City Road	2	Dean Street	1
Claremont Road	2	Eldon Garden	2
Clayton Street	2	Great Park	2
Clayton Street West	2	Leazes Park Road	1
Collingwood Street	2	Quayside	2
Grey Street	1	St Nicholas Avenue	2
The Grove	2	Sandyford Square	2
Leazes Village	1		24
Melbourne Street	2	**NE1 charging points**	
Princes Road	1		
Scotswood-Service Road	1		
Westgate Road	2		
Total	26		

Table 4: NE1 list of public charging points

Time	% of consumption
One hour	24%
One minute	0.40%

Consumption	Time
1% can be consumed in	2.55 min

CP capacity	Power Supply	Charge Time
3kW AC	13/16amp 220-240V	6-8 Hrs.
7kW AC	32amp 220-240V	3-4 Hrs.
21kW AC	32amp 415V	1-2 Hrs.
50kW DC	80amp 415V	20-30 Mins

Figure 7: NE1 inner core main arteries

5.1.1 How the simulation works

The notion of the simulation is to let commuters go through the road network in a nondeterministic manner consuming the battery and originating from a point and reaching random destinations till the battery dies. The logic behind the movement in terms of route choice is based on the configurational analysis done earlier this work. The few number of charging points located in the selected areas have been removed from the modeling so as to run the model while not considering any point of on street/ off street charging points. The model depends only on domestic charging. It works as determining the *behavior layer* of the EVs' drivers when the *critical battery zone* is approached and the driver starts running on almost an empty battery. Several runs are conducted and the number of the stopped cars and the locations of them to be plotted. Via an added counter, the number of stopped cars every iteration is calculated and tabulated in the generated summary report, figure (8).

All the entities are originated from different points beyond the checkpoint (1) as every trip maker lives/ coming different district/ ward. The difference in charging state reflects this assumption. This is reflected by having a normal distribution of the randomness of batteries states. The state of the battery varies between (70%-30%) charged. The more the entity moves nondetermensticly within the network, the consumed the agent state (battery) will be. The battery consumption rate, table above, is according to the bestselling EV in the UK, Nissan LEAF, and adjusted according to its downtown driving mode. The model is developed to count for the number of all generated cars and the number of stopped cars (Critical Battery Zone) ones. Throughout the journey of each entity, there are some events occur while some decisions need to be taken. This is applied via DE and syntactic measures, respectively. The entity is denoted as a movable oval shape, the color of the entity reflects the state of the agent (battery) as the agent starts with blue (30 %< battery <7%), then yellow (20 %< battery <30%), then red (20 %< battery < zero).Once it reaches zero, the dynamic state as of a flat battery mode. The platform is a JAVA script based programs hence all the commands are done whether by adding the class scripts or editing the entities and agents tabs and state charts. The simulation time is to be one day an average of 10 daily mileage nondeterminstically moving within the network.

6. Outcomes

After running several iterations, and calculating the number of stopped cars (measure A) while plotting the location of where the cars most commonly run on empty battery/stopped (measure B), repetitive areas are highlighted to show the plots that are uncovered with charging services. These zones are highlighted in red, figures (8) which are called, critical zones. The outcome of the simulation revealed that an average of 8 cars reaches flat battery state which makes them stopped and turned into gray color. Iterations showed that out of all originated vehicles from the checkpoint 1 (179 EVs), 24 EVs have reached the critical zone battery stage (RED), and 8 EVs of them have stopped. With the model set-up, configurations and programming commands, four zones are identified as critical zones which are (1) Greatmarket B1307, (2) Westgate Road, (3) A168 and (4) Mosley Road, figure (8).

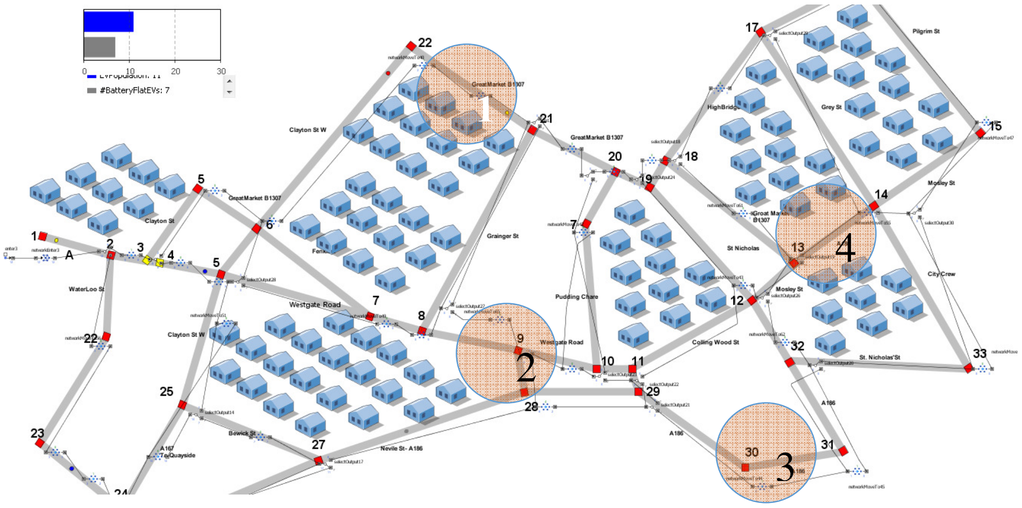


Figure 8: Plotting Critical Zones Diagram

Also from simulation results, some information about denoted road-segments can be observed. Westgate road, the main street which feeds the rest of the network started with 202 entities and ends with 43. This difference goes with all the interactions the entity passes by. Each time, this event takes place and the entity decides way to take based on the configurational measures (pre-calculated table 2).

7. Discussion

A clear delimited and interesting study is presented that works on simulating EV population in a given metropolitan area. The simulation outcomes included two measures which are the ability to count the number of stopped cars in the system network and the zones that most of the cars once entered, they undergo a critical battery and eventually panic hence the range anxiety takes place. This social aspect of the EV system is the main hurdle that stops potential users switching to EVs; nevertheless, abides users to count only on their EV as the one and only choice to commute. Yet, EV is replacing the secondary car in multi-car owning households due to many factors one of which is the irritability of the nondomestic available charging points.

The model provides an approach rather than a tool. As the model has to be adjusted and tailored to emulate a given real EV system likewise the work presents, the inner urban core NE1. The approach is a detailed practice and explained methodology to be employed by planning authorities and policy makers. Since the lack of constructive means of planning, stakeholders need to have decision support mechanism that assists in understanding the reason behind improper planning which leads to scarcely used/ over used charging points in order to avoid the pitfalls in the future planning.

The proposed simulation modeling approach is quite an interactive method as it can be altered and changed depending on several variables to name but a few: (1) planning stage and the purpose of the simulation, (2) the EV system classification, (3) EV urban context and road network size, (4) EV model and mode of driving, (5) logic behind the decisions taken within the road network, and (6) number of users.

To explain how all above can change the outcomes, the first variable is explained. Depending on the planning stage and the purpose of the study, the model setup will be. For instance, if the aim of the simulation is to deactivate some of the currently available on street/ off street charging points in the system, then the charging points will be located and denoted in the simulation. Having said the points are accessible in the simulation environment, the cars will rely on them and use them whenever they need to charge within the simulation iteration time. This will, in turn, affect the outcome of the simulation. As instead of identify the critical zones that need charging service, it will be identifying the zones that will keep the charging service while deactivating the other points located outside the highlighted zones as it has been proved they are underused by the users. Other variables and factors will affect the setup and the measures needed to be monitored which all depend on the planning needs and policies priorities.

8. Conclusion

The multi-model simulation better-served the nature of study problem as being a large-group simulation of active objects that has timing, sequential events, and individual behaviors. The utilization of Anylogic in simulating the EV population was a good choice due to the intuitive and simple ways of hybrid models it has. The topo-geometric and visualized representation of the inner core of NE1 via Depthmap followed by Anylogic draw a methodological approach to assist EV marketers, planners and policy makers. Based on the EV system classification, the model would be adjusted and celebrated to be utilized. The approach basically sheds light on the power of simulation in identifying the gaps of the EVs charging infrastructure. The iterations showed interesting results which can be further elaborated by adding more complexity and making it more at a microscopic level of simulation. The critical highlighted zones reflect a gap in the charging service in these urban areas. The outcome of the study can be read in two ways depends on the purpose and the current stage of planning:

(1) INSTALLATION NEEDED: These critical zones are potential locations charging points to support the users (current or future depends on the size EV population was in the iteration).

(2) REVISITING PLANNING: The charging points fall under these areas are to be activated otherwise other points to be deactivated/ or moved to other critical zones as they will not be used and this will save operational and maintenance running cost.

This paper presents a methodology for alternative means of transport that shall benefit the environment, society and the economy, the triple line approach. This study is considered as a real professional application assisting planning authorities and policy makers. The outcomes can be seen to have played a good enough role in the steps taken towards re-shaping the EV system(s) planning process.

9. Future Work

NE 1 is the inner urban core of Newcastle with a versatile land use and several busy avenues.

More configurational analysis to be applied to study the impact/ relation between the physical properties and the dynamics within the system. More rigorous traffic analysis and counts to be calculated and to be compared with syntactic measures. The outcomes of the models generated as *plotted critical zones* that need charging service are to be compared and studied. The comparison and maybe the overlapping of the two models shall carry out the triangulation process. Models are calibrated and validated by the real information about users we get from the CYC, EV main local service provider.

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